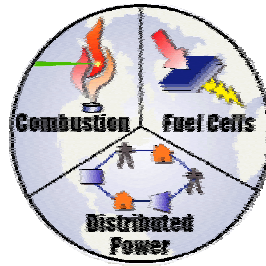


Experiences with MTG Systems Installed in the SCAQMD (and Other Sites in California)



V.G. McDonell

Advanced Power & Energy Program

University of California, Irvine

MTG Users Panel

ASME Turbo Expo 2003

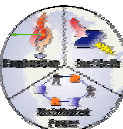
17 June 2003

**Supported by SCAQMD, SC Gas, California Energy Commission,
SC Edison, LADWP, US Department of Defense**

*mcdonell@aep.uci.edu, V:949 824 5950 x121, www.aep.uci.edu

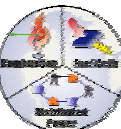
Outline

- **Project Background**
- **General Status**
- **Experience with Example Installations**
- **Concluding Remarks**

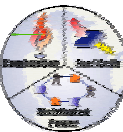
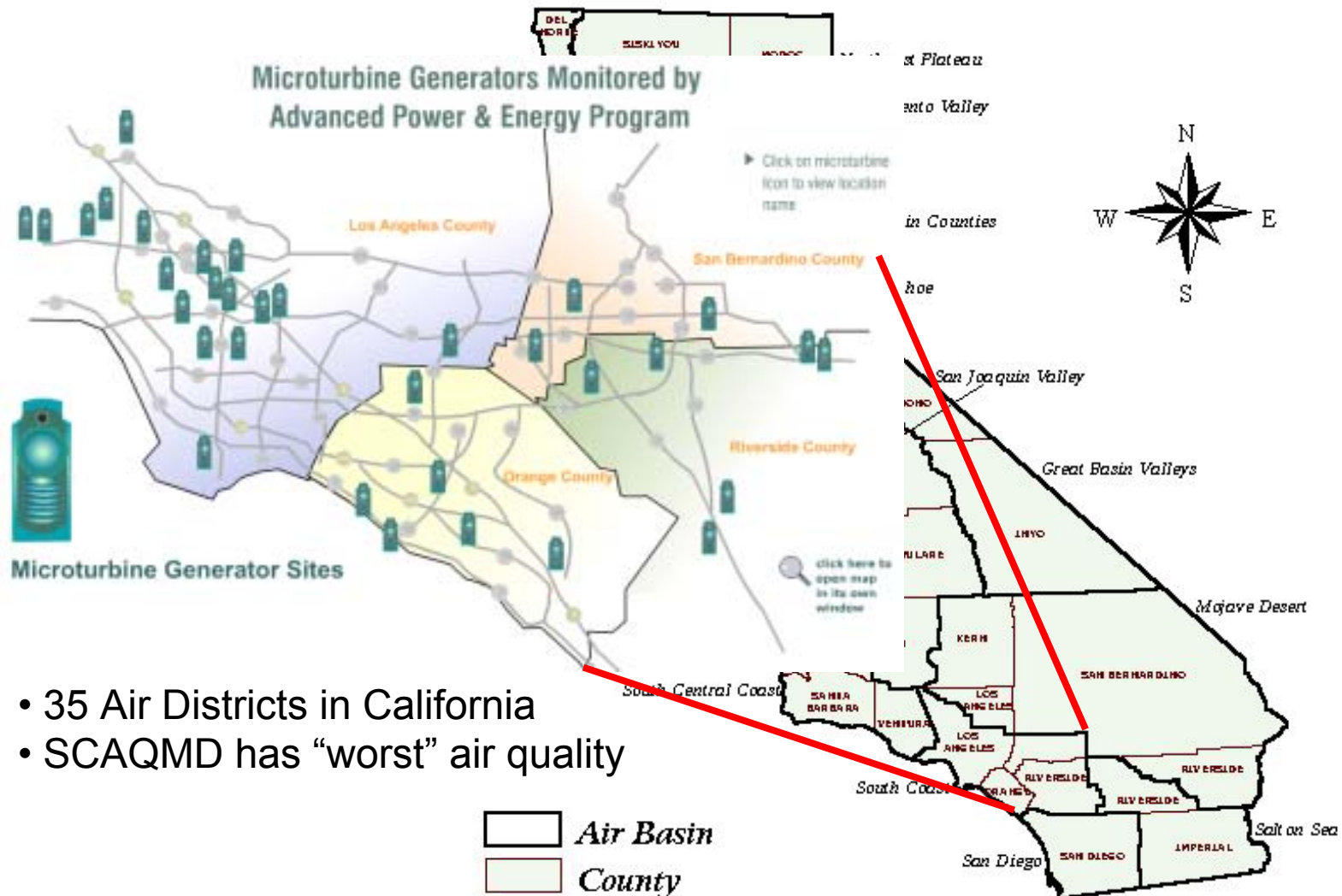


Background

- **SCAQMD Program Inception 4/2001: MTGs offered to interested parties who submitted a description of application**
- **Site Needs/Desires**
 - **3 Phase tie in to power; 480 VAC preferred**
 - **Natural gas available (other fuels possible)**
 - **Sufficient Space for Units**
 - **Understanding/Consideration of Noise Issues**
 - **Ability to use Waste Heat**
- **Approximately 50 sites were selected based on description**
 - **Peak Shave and Grid Parallel Operation Dominant**
 - **Financial assistance offered to help with installation costs**
- **UCI is monitoring all units installed**

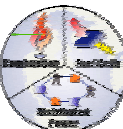


Background

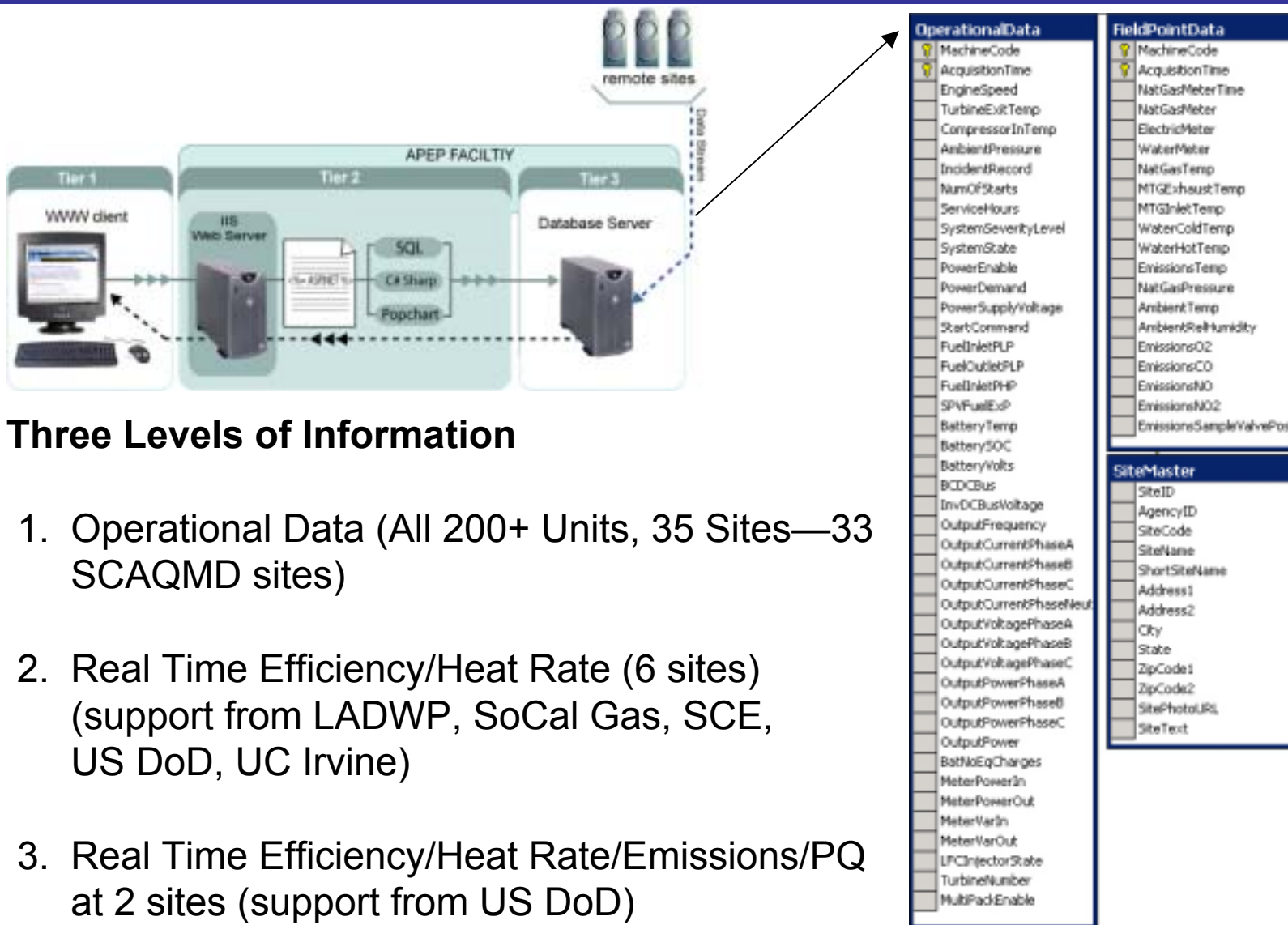


Background

- **US Department of Defense, CERL**
 - Consideration of MTGs for Bases
 - Evaluation, Installation, and Monitoring of MTGs—California Installations
 - Ft. Ord (near Monterey)
 - Pt. Hueneme
- Units will ship to UCI 6/03
- At UCI (7/03-8/03)
 - Evaluate performance w/CEC protocol
 - Add additional sensor equipment
- Install at Final Sites (9/03-11/03)
- UCI Monitor for 18 months

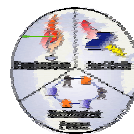


Data Acquisition and Storage



Three Levels of Information

1. Operational Data (All 200+ Units, 35 Sites—33 SCAQMD sites)
2. Real Time Efficiency/Heat Rate (6 sites)
(support from LADWP, SoCal Gas, SCE, US DoD, UC Irvine)
3. Real Time Efficiency/Heat Rate/Emissions/PQ at 2 sites (support from US DoD)



Data Acquisition and Storage

CRMS—Level 1

- SiteID
- Control Date
- Control Time
- Engine Speed (rpm)
- Turbine Exit Temp (°C)
- Compressor In Temp (°C)
- Ambient Pressure (kPa)
- Incident Record
- Starts
- Hours
- System Severity Level
- System State
- Power Enable
- Power Demand (W)
- Power Supply Voltage (V)
- Start Command (0/1)
- Fuel Inlet P LP (kPa)
- Fuel Outlet P LP (kPa)
- Fuel Inlet P HP (kPa)
- SPV Fuel Ex P (kPa)
- Bat Temp (°C)
- Bat SOC (%)
- Bat Volts (Vdc)
- BC DC Bus (V)
- Inv DC Bus Volts (Vdc)
- Output Frequency (Hz)
- Output Current Phase A (A)
- Output Current Phase B (A)
- Output Current Phase C (A)
- Output Current Neutral (A)
- Output Voltage Phase A (V)
- Output Voltage Phase B (V)
- Output Voltage Phase C (V)
- Output Power Phase A (W)
- Output Power Phase B (W)
- Output Power Phase C (W)
- Output Power (W)
- Bat No. Eq. Charges
- Meter Watts In (W)
- Meter Watts Out (W)
- Meter VAR In (VAR)
- Meter VAR Out (VAR)
- LFC Injector State
- Turbine Number
- Multi-Pack Enable

Level 3 Site Data

LabVIEW

- SiteID
- Date/Time
- Interval
- NGVolume
- ElectricEnergy
- WaterVolume
- NGTemp
- MTGExhaust
- MTGInlet
- WaterCold
- WaterHot
- EmmissionSample
- AmbTemp
- NGPressure
- AmbTemp
- AmbRH
- EmissO2
- EmissCO
- EmissNO
- EmissCO2

Nexus PQ

- SiteID
- Date/Time
- ms
- Type
- Volts AN
- Volts BN
- Volts CN
- I A
- I B
- I C
- Frequency
- % THD Volts AN
- % THD Volts BN
- % THD Volts CN
- % THD IA
- % THD IB
- % THD IC
- Power Factor T
- Avg Watt T
- Watt A
- Watt B
- Watt C
- Watt T



Data Acquisition and Storage


South Coast Air Quality Management District
APEP
NFERC
UCIEL



MICROTURBINE GENERATOR PROGRAM

Tuesday, January 29, 2003 11:07:46 PM PST University of California, Irvine

[Home](#)
[Map of Monitored Sites \(flash required\)](#)
[\(Download Flash Player\)](#)
[View Site Summary](#)
[Glossary](#)

DATA CHARTS

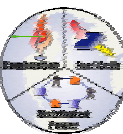
To view data charts for one day, week, month or quarter select the site #, machine # and data period

DATA GRID: Overview of Site summary

Click on the Site below to view additional information about the Site.

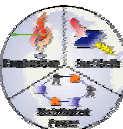
Show summary data for month of

Latest Readings					Summary Data							
Site No.	Status	As Of	Current Output	Start Of Data Collection	Total Operating Hours	Total Output Power ^h	Totals for 12/2002			ON Peak 12/2002		
			kW			(kWh)	Operating Hours	Power Output (kWh)	% Capacity	Operating Hours	Power Output (kWh)	% Capacity
Site 1												
Machine #1	Lead	01/28/03 06:55	59.93	05/08/2002	10,257	239,240	744	44,188	99	132	7,734	98
Machine #2	Lead	01/28/03 06:40	59.90	07/09/2002	9,017	81,284	N/A	0	0	0	0	0
Machine #3	Lead	01/28/03 09:50	57.89	07/09/2002	10,892	211,834	744	43,891	98	132	7,625	96
Site 2												
Machine #1	Stand By	01/28/03 11:50	0.00	06/07/2002	1,552	16,263	96	2,266	10	59	1,420	36
Machine #2	Stand By	01/28/03 12:00	0.00	06/07/2002	1,090	19,508	139	3,509	16	87	2,112	53
Machine #3	Stand By	01/28/03 11:50	0.00	06/07/2002	1,827	14,809	147	3,459	15	87	2,093	53
Machine #4	Stand By	01/28/03 11:50	0.00	06/07/2002	1,692	16,451	122	2,947	13	72	1,794	45
Machine #5	Lead	01/28/03 11:50	25.15	05/03/2002	2,182	19,074	149	3,761	17	89	2,271	57
Machine #6	Lead	01/28/03 11:50	24.99	05/03/2002	1,828	24,507	149	3,740	17	89	2,254	57
Site 3												
Machine #1	Lead	01/28/03 20:50	29.26	05/24/2002	8,634	129,277	457	13,135	59	77	2,220	56
Machine #2	Lead	01/28/03 20:50	28.99	05/24/2002	8,756	104,199	280	7,642	36	58	1,383	35
Site 4												
Machine #1	Lead	01/28/03 06:45	29.02	08/06/2002	6,414	73,248	690	19,620	88	118	3,402	86



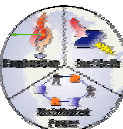
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- **General Status**
- **Experience with Example Installations**
- **Concluding Remarks**



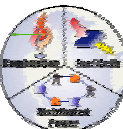
General Status: SCAQMD (5/2003)

- **First site operational 8/7/01 (UC Irvine)**
 - limited by MTG availability for delivery
- **30% of originally selected sites “backed out”:**
 - installation costs realities (majority)
 - other installation issues
- **33 Sites currently “active”**
- **Approximately 20 sites are operational (at some level)**
- **11 are operating reliably and consistently.**
- **What were some of the issues encountered?**



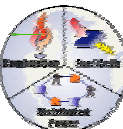
General Issues: SCAQMD

- **Utility Permitting (3+ month process)**
 - **Electric Interconnect**
 - Adds Delay and Cost (Despite Improvements)
 - **Gas**
 - Confirmation of Service Capacity
- **Local Building Authority**
 - City “education” relative to technology
 - Noise Considerations
- **Air Quality Authority**
 - SCAQMD—No permit required with $<2\text{MMBTU/hr}$ firing rate
 - SB1298 may come into play (1/1/03, CA)
 - Exception: Operation on Landfill or Digester Gas



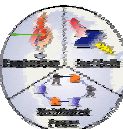
General Issues: SCAQMD

- **Other Authorities**
 - **Public Schools/Institutions**
 - Office of State Architect (e.g., LA City College)
 - Requirement apparently depends on location/jurisdiction
 - **Hospitals (9 month+ delay)**
 - OSHPD (approval time depends upon the division/district)
- **Installation Cost Issues**
 - Although some \$ were provided for installation, many sites were not prepared to provide additional funds
 - Lack of an integrated package
 - Single unit installations on per kW basis appear unattractive
- **Operation Cost Issues**
 - Some sites postponed commissioning due to uncertainty in electric rates



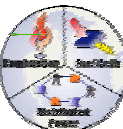
General Issues: DoD

- **Project schedule allowed “Lessons Learned” from AQMD program to be applied**
- **Installation Strategy**
 - **Single nationwide organization desired**
 - **Terms and Conditions of University AND DoD proved imposing to organizations not familiar with gov’t contracting such as smaller local companies**



Outline

- Project Background
- General Status
- **Experience with Example Installations**
- **Concluding Remarks**



Example Installation--CSUN

- 6 Capstone 330 MTGs w/2 Microgen HX provided by AQMD
- Open, indoor location in Central plant (noise not issue)
 - Nominal 10 psig gas service
 - “On-board” gas compressor used
 - Electrical Tie-In convenient (3 ph 480V)
 - Telephone and Ethernet communications available
- CHP used to augment space heating and DHW needs.
 - Preheat of return feedwater to boilers
 - Good size match on heat loads
 - Heat exchangers ganged;
one 4 MTG unit and one 2 MTG unit
- Multi-pak operation (4 units + 2 units)
- ~\$80,000 installation cost (\$450/kw)
 - Pad, gas plumbing, electrical,
water interconnection
- Commissioned in Dec 2001



Example Installation--CSUN

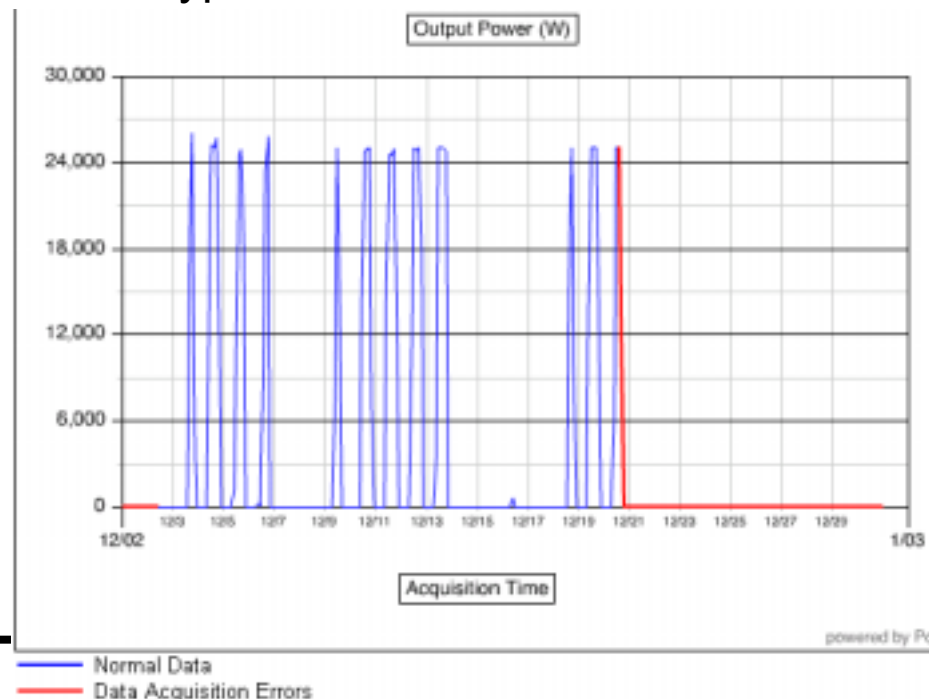
- **Commissioning Issues**
 - Natural Gas Service sizing; required upgrade in piping size.
 - Exhaust leaks from heat exchangers
 - Multi-pack control issues
- **Operational Experiences**
 - Total kw-hr/Possible kw-hr
 - 43% 10/02 to 5/03
 - Down time associated more with communications and software control rather than mechanical component failure.
 - CHP integration: Significant heat/energy loss of “preheated feedwater” entering cold boiler.



Example Installation--CSUN

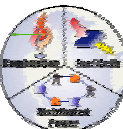
- **Time of day use:**
 - approx 10 am to 8 pm (“mid-peak” and “peak” time table)
 - units operated at “base load” (i.e., full power) when running
 - Units have 1,900 to 2,400 hrs each (through 5/03)
- **Economics difficult to assess**
 - Natural Gas: “core” rates from Southern California Gas
 - Electric Power Rate structure still not finalized
 - Originally on LADWP S-3 rate structure
 - LADWP announced review of S-3 at approximately same time units were commissioned.
 - Still not finalized

Typical Load Profile—Machine #1



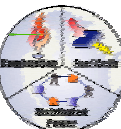
Example Installation—Allergan

- **Pharmaceutical R&D location (Irvine, CA)**
 - Large electrical demand
 - Substantial hot water/space heating
 - Displace planned diesel recip (reduce emissions)
 - Mitigate need to replace failing existing boiler (reduce emissions)
- **2 Capstone C-60 MTGs with Microgen HX for one**
- **Contained within existing equipment room**
 - Tight arrangement makes equipment movement difficult
 - Noise not an issue
 - Electric tie-in, 480V
 - Gas nearby
 - Phone installation needed



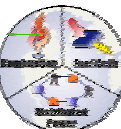
Example Installation—Allergan

- **Timeline**
 - Mar 02—requested 4 60 kW MTGs
 - Jun 02—granted 2 60 kW MTGs w/dual mode operation
 - Oct 02—Dec 02—Initial Installation
 - Jan 03—UL certification required by City
 - Feb 03--Installation dismantled and UL certified version installed and approved by City
 - Feb 03 – May 03 Commissioning issues
- **Interconnection Experience**
 - SCE required meters to be installed for each unit (\$7,000) which will never be read (Allergan prohibited from selling power to SCE)
 - SCE failed two applications based on measured protective relay settings being outside of requirements
 - Third application was approved after SCE provided Capstone with the required settings



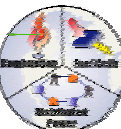
Example Installation—Allergan

- **Operational Experience: General**
 - Exhaust dampers installed have been unreliable
 - One seized closed-may have resulted in engine failure
 - Temperature Issues
 - Ducting Insulation insufficient—room temps over 115 F
 - Allergan added insulation and had to increase room ventilation to mitigate
 - More system heat was generated than suggested by specs
- **Operational Experience: MTGs**
 - Unit 1 (w/heat recovery)—major startup/operational issues
 - Multiple Cooling Fans, Controller boards failed/replaced
 - Still not truly operation (5/03)
 - Backup boiler installed
 - Unit 2
 - Also problems with cooling fans
 - Has operated ~1500 hrs out of 3000 desired since Feb 03



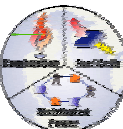
Example Installation—Allergan

- **Self Gen Incentive Experience**
 - Allergan applied for \$36,000 rebate from CEC through SCE in Oct 2002
 - Several letters received requesting additional information
 - Same information requested and provided to SCE multiple times
 - Final application submitted in May 2003
 - Delays due to operational issues
 - Must be finalized by Dec 2003



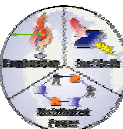
Example Installation—Allergan

- **Costs**
 - **Project Cost was budgeted at \$190,000**
 - Removal of existing boiler, ducting, prepping room
 - Heat Exchanger for the MTGs (~\$12,000 for HX)
 - Installation of new equipment, ducting
 - \$1,483/kW for installation
 - **Actual Costs (through 5/03)**
 - \$260,000 which includes removal/reinstall of MTG equipment, ducting, adding/reinstalling additional insulation, increased room ventilation



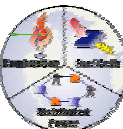
Example Installation--SMWD

- Chiquita Water Reclamation Plant (2 Capstone 330 MTGs w/ 1 Microgen Heat Exchanger provided by AQMD)
- Open, outdoor space (noise not an issue)
 - Convenient electric tie-in, 480V 3ph
 - Phone installation needed
- SMWD has ordered (and is paying for) 2 more units
Installation to begin 6/23/03
- Operation on digester gas
- Multipak Operation
- Installation Cost: \$83,666
 - Gas cleanup, connections, site prep, interconnect (\$1,400), air permit (\$1,611), source test (\$8,815)



Example Installation--SMWD

- **Current CHP provides all necessary heating for digesters.**
 - 2 boilers on-site – 1 is off and the other on stand-by
 - Heat from 2 new MTGs will heat 3rd (future) digester and/or dry sludge for transport



Example Installation--SMWD

- **Operational Experience**
 - Commissioned end of December, 2001
 - 10,800 hours operation on each machine (5/03)
>530,000 kW-hr generated
 - Pleased with technology – first 2 units operating reliably
90% strict reliability (operating/calendar time) as of May 2003
 - Service
 - Typically slow responding
 - Typically slow resolving
 - Typical operating
cost savings: ~\$4,000-
\$5,000 per month
 - Several delays in finding
contractor to install 3rd
and 4th turbines



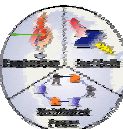
Example Installation—UC Irvine

- **3 Capstone C-60's, No CHP utilization**
- **Gas pressure variable from few inches to 150 psig**
- **Adjacent to Laboratory Facility**
 - Sound concerns to residences 0.25-0.5 miles from site
 - \$7,500 study to approve
- **Additional 480 V 600 A Tie-in**
 - Existing interconnect OK
- **Ethernet and Phone available**
- **Campus Authorities required 4 months and \$21,850 to develop and review plans**
- **Installation Cost: \$71,500**
 - Electrical, gas meter, conduit, protections, gauges, labor, campus plans/management
- **Commissioned Aug 2001**



Example Installation—UC Irvine

- **Commissioning Issues**
 - **Software Versions were initially incorrect, resolved in 10 days**
- **Operational Experience**
 - **Strict Availability (83, 87, 88%) 8/01 to 8/02**
 - **Availability Accounting for Non-MTG Downtime (94.5, 99.4, 100%) (8/01 to 8/02)**
 - **In Oct 02, Smart Proportional Valve failed on two units, replaced within 2 days by on-site Authorized Service Provider**
 - **April 03, gas compressor serviced**
 - **Strict Availability (84, 76, 88%) 8/01 to 5/03**
 - **“Low” Units undergoing research tests and procedures**
 - **13,300, 12,117, 14,006 hours on each unit (through 5/03)**
 - **5/03 Operating Software Upgraded**



Example Installation—Ft. Ord

- **Childcare Center (Ft. Ord military community, Monterey CA)**
 - 90kW peak demand, several outages each year
 - Substantial hot water/space heating
- **1 Capstone C-60 MTG with Integrated Heat Exchanger Package (new), Dual Mode Operation**
- **Location adjacent to building entrance**
 - Noise may be an issue
 - Electric tie-in nearby
 - Gas nearby
 - Phone installation needed
- **Cost Estimates:**
 - Equipment: \$72,830
 - Installation \$85,680
 - \$1428/kW
 - Includes 2 yr service
 - Doesn't include load isolation work



Example Installation—Ft. Ord

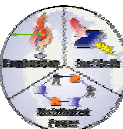
- **Schedule**
 - Unit scheduled to ship 6/03
 - Arrive at UCI for lab evaluation (7/03)
 - Test Protocol from CEC Funding
 - Installation at Ft Ord 9/03—11/03
 - Will include Level 3 monitoring
 - Heat Rate
 - Emissions
 - Power Quality
 - Capstone Data
 - Monitoring for 18 months



Example Installations: Summary

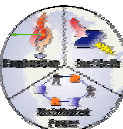
Site	Units	Total kw	CHP?	Dual Mode?	Fuel
CSUN	6	180	Y	N	Nat Gas
RSM	2	60	Y	N	Digester
UCI	3	180	N	N	Nat Gas
Allergan	2	120	Y	Y	Nat Gas
Ft. Ord	1	60	Y	Y	Nat Gas
Pt Hueneme	1	60	Y	N	Nat Gas

Site	Installation Experience	Installation Total per Unit per kW			Reliability
CSUN	minor problems	\$80,000	\$13,333	\$444	fair
RSM	minor problems	\$83,666	\$41,833	\$1,394	good
UCI	sound, campus	\$71,500	\$23,833	\$397	excellent
Allergan	equip probs, utility	\$178,000	\$89,000	\$1,483	poor
Ft. Ord	TBD	\$85,680	\$85,680	\$1,428	TBD
Pt Hueneme	TBD	\$49,834	\$49,834	\$830	TBD



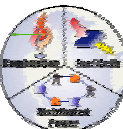
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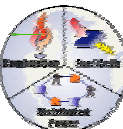
Concluding Remarks (1/2)

- **Capstone technology is delivering claimed performance**
 - Emissions, Efficiency, Acoustics, PQ (spot check basis)
- **Reliability/Availability**
 - Capstone C-60 and 330 products are improving in reliability
 - Need standard definition/data logging procedures to better quantify improvements
 - Need field experience and lab experience with logging
 - Issues tend to occur early if at all
- **Customers want solutions not technology**
 - Lack of standard practice/information
 - Permitting, installation, schedule have uncertainty
 - Policy consistent with large scale generation doesn't fit MTGs
 - Knowledge base is increasing, but at slow pace
 - Service/Repair history is less than ideal (too long to resolve problems)



Concluding Remarks (2/2)

- **Uncertain market is creating decision challenges**
 - Fuel price vs electricity cost—California is attractive for now
 - “Free fuel” applications appear to work well
 - Using waste heat helps ensure payback
- **Installation Costs are a Major Hurdle**
 - Single Unit Installation are relatively expensive
 - \$14,000 per unit (6 MTGs w CHP)
 - \$24,000 per unit (3 MTGs w/no CHP)
 - \$42,000 per unit (2 MTGs w/CHP & fuel gas clean up)
 - \$49,800 per unit (1 MTG w/CHP)
 - Integrated/Packaged units should help reduce costs
 - Each Installation has minimum fixed costs
 - More options needed
 - Integrated maintenance package needed to help service provider recognize consistent cash flow



Microturbine Generators Monitored by Advanced Power & Energy Program

www.apep.uci.edu/aqmd

207+ Units

